THE COMPOSITION AND UTILIZATION OF WOOD TAR

BY

G. B. JAMES

H. SIECK

ARMOUR INSTITUTE OF TECHNOLOGY

1911

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The composition and
 utilization of wood tar

THE COMPOSITION AND UTILIZATION OF WOOD TAR.

A THESIS

PRESENTED BY

GARRETT B. JAMES

and

HERBERT SIECK

to the

PRESIDENT AND FACULTY

of

ARMOUR INSTITUTE OF TECNOLOGY

FOR THE DEGREE OF

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HAVING COMPLETED THE PRESCRIBED COURSE

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1911

APPROVED Harry McCormack ....

Professor of Chemical Engineering.

H. M. Raymond ....

Dean of Engineering Studies.

L. C. Monin

Dean of Cultural Studies

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The Composition and Utilization of Wood Tar.

Of the various processes employed for the manufacturing chemical compounds from wood, that of destructive distillation is probably at present the most important. The industry is an old one, and is quite well developed in Germany, Russia, Norway, and Sweden, and less extensively in France and England.

A preliminary report of the U. S. census Bureau gives the following summary of the operations in 1909 of the 116 hardwood distillation plants using 1150000 cords of beech, birch, maple etc.

The report as reprinted in the Chemical Engineer:-

Charcoal, bushels	53,075,000	Value $	3,299,000.
Crude Alcohol, gals.	8,468,000		2,082,000.
Gray Acetate, lbs.	148,769,000		2,203,000.
Brown Acetate, lbs.	2,157,000		22,000.
Pitch and Oils			3,000.

From the above may be seen the extent of the industry in the United States and also the small market value of the oils and pitch placed on the market.

The data on the composition of wood, the basis of this great industry, are not very satisfactory as the figures were obtained

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by methods less accurate than those now in use. In the following analyses, made by Hugo Muller, the figures for water extract include tannins, coloring matter, sugars, starches, etc.

Analysis of various Woods. (Muller)

	Water	Water ext.	Resins	Cellulose	Incrusting matter.
Birch	12.48	2.65	1.14	55.52	28.21
Beech	12.57	2.41	.41	45.47	39.14
Oak	13.12	12.20	.91	39.47	34.30
Alder	10.70	2.48	.87	54.62	31.33

It may be said further with reference to these figures that at present no definite relation can be established between the composition of woods and the chief distillation products obtained from them, namely, alcohol, acetone, acetic acid, and charcoal. The data available indicate that cellulose gives maximum yields of methyl alcohol and but little acetic acid when subjected to destructive distillation, the latter product being evidently derived from the more unstable " incrusting matter ".

A general idea as to the yield of distillation products can be obtained from the following results obtained by the authors on the distillation of maple.

The wood used had been kiln dried and contained practically no moisture. Since the best results are obtained with wood con-

taining 20 % moisture the wood was allowed to soak up this amount before distilling. The distillation was carried out in a cylindrical copper retort about 5 inches in diameter and 8 inches high.

This was connected to a liebig condenser and then thru two large bottles to catch the distillate. From here the gases passed thru a Sargent Wet Test Gas Meter.

Heat was furnished by a ring burner with the aid of a blast lamp at the end of the distillation. No attempt was made to meter the gas used for heating.

The first distillate was a strong smelling dark brown liquid mixed with about 10 % of tar which slowly settled out on standing. The tar and liquid were separated in a separatory funnel and the tar returned to the still after the charcoal had been removed.

During the run the gas was analyzed in a Morehead Gas burette and the average composition determined from which the weight could be calculated since the volume was recorded by the meter.

The first liquor mechanically separated from the tar was redistilled and the "boiled tar" left in the still mixed with the mechanically separated tar. A calorific test run on this mixture showed a heat value of 8610 B.T.U. per pound.

This tar mixture was redistilled and the four fractions shown in the table obtained. The middle oils were treated with NaOH and the washings then treated with H_2SO_4. On heating this mixture the odor of creosote was easily noticeable.

A B.T.U. determination made on the heavy oils showed 9350 B.TU. per pound.

The distilled liquor was titrated and found to contain 162 gms. or 8.17 % acid calculated to acetic acid. Milk of lime, the calculated amount, was added and enough more until the mixture assumed an orange color. During this addition of lime the mixture changes from black to green, then to a deep red and finally to the orange end point. This neutralized liquor was put into a large flask and distilled thru a column containing small glass funnels. Everything which came over below 96°C was taken and this distillate redistilled with a Glinsky column Till the temperature reached 68°. This distillate contained the alcohol and a very little acetone and no attempt was made to separate them.

The residue in the flask was evaporated to the point of crystalization and the calcium acetate crystal removed and dried on a hot iron plate.

Plate I gives the yield, specific gravity, and purity of the products as obtained.

In all five runs were made. The total numbers of liters of gas was 683.6. The analyses of gases from three of the runs follow:-

	CO_2	CO	Ill.	O	CH_4	H	N (by diff.)
(1)	44.0	32.0	1.0	3.1	.4	1.1	18.4
(2)	43.4	32.6	1.4	3.4	1.0	5.6	12.6

	CO_2	CO	Ill.	O	CH_4	H	N	
(3)	28.4	32.8	3.0	4.8	.4	4.0	26.6	
	38.6	32.5	1.8	3.8	.6	3.8	19.2	Average.

The results on the gases agree fairly well with those given by Veitch with the evception of the CO_2 which he gives as 53.0 % and the highest obtained by the authors was 44.0 %. This variation may be due to differences in the speed and temperature of the carbonization.

The above results reduced to percentages give:-

Tar	13.5 %
Gases	21.6
Distillate (aqueous)	41.4
Charcoal	20.2
Loss (unaccounted for)	3.3

The loss 3.3 % can be charged up against the gases since the weight was only calculated from what were supposed to be true average compositions.

In a large wood distillation plant the procedure is essentially the same differing only in the magnitude of the operations. Plate [illegible] II shows the passage of the material thru the plant. This diagram was taken from the plan of a modern wood distillery in upper Michigan the daily capacity of which is 225 cords. As can be seen the tar after being separated is distilled for its alcohol content and then burned under the retorts. It is the

object of this thesis to determine the composition of this tar and its various constituents and if possible derive new uses for these products.

Sample of Tar Used in the Work.

The tar used in this investigation was the crude tar taken directly out of the tar separators, as shown in Plate II.

It was a thick, dark colored, viscous material of specific gravity 1.045. On standing for some time a considerable amount of clear liquor came to the top and was decanted. This weighed 7.8 % of the weight of the tar and will be referred to later as 02.

The separated tar was thoroughly mixed and a sample taken for analysis which showed:-

C	59.60 %
H	7.81
O	30.30
N	2.18
Ash	.11

There was absolutely no trace of sulphur.

Distillation of the Tar.

The distillation was conducted in an copper still of 10 lbs. capacity. The still was cylindrical and was fitted with a flat head thru which the outlet pipe and thermometr hole were fitted.

The vapors were condensed in a glass Liebig condenser, 1/2 inch inside diameter and 30 inches long. It was supplied with cold water at about 20°C. The total weight of the tar used in the first distillation was 9.82 lbs.

The still was gradually heated and the first distillate came over at 85°C. This distillate was a clear liquid with the odor of wood alcolhol. A light yellow liquid next came over at about 99°C. along with a small quantity of dark brown oil which floated on top. The receiver was changed when the temperature reached 118°. This will be designated as cut no. 1 the weight of which was 1.26 lbs.

The dark brown oil was next collected up to 175° this fraction being known as cut no. 2 and weighing .66 lbs.

Cuts nos. 3, 4, and 5 contained a lemon yellow, highly refractive oil which was noticed coming over at 140° in cut no. 2. The combined weight of these cuts was 1.710 lbs.

At 250° C. it was noticed that the distillate was solidifying in the condenser so the receiver was changed this giving cut no. 6. To prevent the distillate from solidifying in the condenser the water was shut off and a current of air drawn thry the condenser jacket. This fraction was continued up to 263° C. and weighed .610 lbs. The temperature at the various times during the distillation can be seen from Plate III where the temperatures are plotted against the time.

The pitch remaining was weighed in the still.

The Separation of the various Fractions.

The cuts first obtained were separated according to specific gravities in a separatory funnel and the following homogeneous fractions obtained:-

Mark 12.

Contains the lowerelayer of cut no. 1. Is aliquid, about the consistency of water, light yellow in color and having a slight odor of acetone and alcohol.

Weight 1.13 lbs.
Sp. Gravity at 14.4° 1.008

Mark 22.

Contains the top oily layer of the first cut and the whole of cut no. 2 stopped at 175°. Is an oily liquid, does not mix with water and has a dark redish brown color. It has a strong odor suggestive of smoldreing wood.

Weight .81 lbs.
Sp. Gravity at 15.0° .975

Mark 32.

Contains the bottom layers of cuts nos. 3,4, and 5. Is a highly refractive oil, bright lemon yellow color when freshly distilled but turned to a dark redish brown color on standing. It has an odor of creosote and phenol. On standing for some

time a watery substance rose to the top. This is included under 42.

Mark 42.

Top layer of 3, 4, and 5. Is a white rather oily liquid with a strong disagreeable odor. Probably the water of hydration of some of the high boiling compounds.

Weight	.05 lbs.
Sp. Gravity at 19°.	1.011

Mark 52.

Last fraction. Solidifies on cooling to a semi-solid crystalline mass. Is a dirty greenish yellow color but turns to red on standing. The solid was filtered off and is included under 62.

Weight	.610 lbs.
Sp. Gravity at 16°	1.055

Mark 62. Solid filtered out of 52. Is a paraffin like body melting at 62° C

Mark 72.

Is the pitch remaining in the still. A hard, somewhat brittle, homogeneous mass.

Weight	5.01 lbs.
Sp. Gravity	1.194

The various frations and their origin is shown in the following table :-

02

Mechanically separated acid water from the tar.

03

Distillate from neutralized 02.

12

Acid water first distilled from the tar.

13

Distillate from neutralized 12.

14

Residue from the distillation of neutralized 12.

22

Light oils. part of cut 1 and all of 2.

32

All of cuts 3, 4, and 5 with the exception of the supernatant lquid.

42

The supernatant liquid above referred to.

52

Clear liquid from cut 6.

62

Paraffin body filtered out of 52.

72

Pitch.

Balance of Results:-

Weight of

Fraction	12	1.13 lbs.	
	22	.81	
	32	1.67	
	42	.05	
	52	.61	
	72	5.01	
Loss accounted for		.22	
Loss unaccounted for		.33	= 3.3 %.

The separate fractions were then treated and the following data obtained relative to their composition.

Mark 02.

The weight of this liquor is 7.8 % of the weight of the tar. It was titrated with KOH and found to contain 12.55 % acid calculated to acetic acid. It was neutralized by the addition of .10 lbs. of lime to 2.46 lbs. of the liquor and distilled with a rectifying column.

The fration coming over below 95° was collected and is known as 03.

Mark 03.

Weight .135 lbs.

An analysis of this liquid showed:-

	By Volume	By Weight.
Per cent Methyl Alcohol	10.10	8.25
Acetone	8.24	6.76
Water	81.66	84.99

From the above the composition of 02 can be calculated and is found to be:-

	By Weight
Per cent Methyl Alcohol	.453
Acetone	.371
Acetic acid	12.55
Water	88.626

Note. The small quantities of alcohol and acetone in 02 necessitated their concentration into 03 for analysis.

Mark 13.

This liquor was tirated with KOH and found to contain 11.8 % acid calculated to acetic acid. This acid was neutralized with lime and 1.04 lbs. distilled from a glass flask fitted with a Glinsky tube, the vapors being condensed in a condenser of the Liebig type. The distillation was stopped when the temperature reached 99° C.

The distillate to be known as 13 and the residue as 14.

Mark 13.

Weight		.175 lbs.
Sp. Gravity at 23° C.		.9310

		By Weight	By Volume.
Per cent	Acetone	13.82	16.50
	Methyl Alcohol	22.81	26.96
	Water	63.37	56.53

The composition of 12 could thus be calculated and was found to be:-

Per cent	Acetic acid	11.8
	Methyl alcohol	3.54
	Acetone	2.14
	Water	82.52

Mark 14.

This is the residue from the alcohol distillation. Is abrown-red solution containing a large quantity of undissolved lime in suspension. This insoluble part was filtered off amd evaporated to dryness.

Weight	.085 lbs.
Per cent Acetate of lime	35.30

The solution was also evaporated to dryness and the acetate which was of a yellow white color recovered.

Weight	.095 lbs.
Per cent Acetate of lime	64.20

Acetic acid was determined by distillation of the acetate

with phosphoric acid and subsequent titration of the acetic acid formed with alkali.

Mark 22.

Was washed first with 10 % NaOH until further washings with the alkali produced no appreciable diminution of volume. The successive volumes on treating 80 ccms. of the oil with 20 ccms. portions of 10 % NaOH were : 80, 54, 38, 33, and 31 ccms. The remainder was washed with water until neutral boiled with bone black and filtered. A clear dark red oil, with a smell resembling some of the benzene bodies was obtained.

The following properties were then determined:-

Sp. Gravity at 15°.	.975
Index Refraction	1.4690
Kottsdorfer Number	67.10
Iodine value	105.0
Boiling point	122.° C.
Freezing point	-9.°

An ultimate analysis of the above oil gave the following composition:-

C	50.8
H	9.1
O	39.18
N	.92

Mark 32

(Creosote Oil)

An analysis of this oil showed the following properties:-

Index Refraction	1.5028
Kottsdorfer number	170.30
Free fatty acids (Equivalent Mgs. KOH)	75.80
Iodine value	257.50

An ultimate analysis of this oil gave the following result:

C	62.70
H	7.60
N	.69
O	30.01

The heat of combustion as determined in the Mahler Bomb Calorimeter was found to be 12,240 B.T.U. per Lb.

The oil was valued according to a method given by Allen for the valuation of wood creosote oils.

Sp. Gravity at 15°	1.056
Per cent distilling below 100°	9.6
from 100° to 200°	19.05
from 200 to 205°	5.35
from 205° to 210°	5.85

from 210° to 215°	7.82
from 215° to 220°	6.55
from 220° to 240°	24.74
from 240° up	19.32

The number of ccms. of 7.5 % solution of NaOH required to dissolve 2 ccms. of the oil was 9.70.

The oil gave a decided reaction with baryta water and increased in volume.

When mixed with a 20 % solution of KOH in alcohol a crystalline precipitate is formed almost immediately.

Mark 52.

This oil after the solid had been removed was practically the same as 32 as was verified by the following analysis.

C	61.60
H	7.62
N	.70
O	30.08

Mark 62.

This is the solid portion filtered out of 52. It was boiled with dilute sulphuric acid and reboiled with water. On cooling it hardened to a consistency about the same as paraffin with the same color and texture. The amount recoverable was so small that

it was not thought profitable to investigate further into its composition. It is probably the paraffin $C_{20}H_{42}$ isolated and described by Thenius.

Mark 72.

Pitch solidified to a hard, rather easily broken mass of a shiny black color.

Weight	5.01 lbs.
Specific Gravity	1.194
Melting point	126.0°C
Open Flash Point	210.0°
Burning point	225.0°
Fixed carbon per cent	23.18
Soluble in carbon bisulphide	54.31
Soluble in carbon tetra-chloride	37.64
Mineral	.16

The following solutions had no effect on the pitch:

Saturated NaCl	20 % NH_4OH
25 % H_2SO_4	35 % HCl

An ultimate analysis of the pitch gave:

C	73.30
H	7.31
O	15.80
N	3.59

On combustion in the Mahler calorimeter the pitch showed a heat value of 14040 B.T.U. per lbs.

In an endeavor to locate the cause of the unaccounted for loss during the distillation the elements were checked as follows. The different fractions were reduced to their component elements and the weights of these checked against the weights of the separate elements in the original tar.

Fraction	Wgt. C	H	O	N
12	.0834	.120	.9296	.000
22	.420	.073	.318	.0074
32	1.048	.127	.501	.0115
52	.376	.0465	.1835	.0042
72	3.70	.366	.79	.179
Total	5.627	.7325	2.7216	.2021
Tar	5.713	.7497	2.909	.2082

The unaccounted for loss can now be analyzed. From the balance it can be seen to consist of:-

C	.086 lbs.
O	.187
H	.017
N	.0061

From these figures it seems highly probable that the loss was

mainly composed of CO and CO_2 the proportions being approximately 30 % CO and 70 % CO_2.

Discussion of Results.

The products will now be discussed in their order with reference to probable chemical composition and utilization.

02

This liquor is really of small importance except for the recovery of the small amounts of alcohol, acetone, acetic acid which it contains. The settling of the tar out of this liquor as is now practiced is slow and unsatisfactory as to the degree of separation.

It has been found by previous experimenters that when a high tension electric current is passed thru a fluid holding another insoluble fluid in suspension it causes the immediate precipitation of one of these bodies. In the case at hand the tar could be separated from the liquor by the passage of such a high tension current.

To determine whether or not such a process would be profitable it was necessary to know the amount of power consumed by such a machine during its operation. For this calculation the resistance of the tar at the various temperatures must be known.

This was determined by the fall of potential method, the tar being contained in a wooden trough. The results obtained are shown in Plate IV where the specific resistance, in the metric

system , is plotted against the temperature in degrees centigrade. It will be seen that at lower temperatures the tar is almost an insulator or nonconductor and that the conductivity increase rapidly with increase in temperature.

Plate V shows a proposed machine for this operation.

The tar is made to flow thru the intake and between copper plates at the rate of about 1 foot per sec. The plates are about 1 1/2 inches apart gradually diverging to 5 inches at the farther end. The tar is thrown down and passes under the wall in the tar well leaving the latter thru the open~~n~~ing C. This opening should be of such size that when the tar is passing thru the machine the level in the well should remain at H or high enough to permit the caid water to pass off over the overflow C.

A plant using 225 cords of wood per day would handle about 90000 lbs. of acid water and tar per day. Assuming that this tar is to pass thru the apparatus in 4 hours the flow would be at the rate of 0.10 cu. ft. per sec. Allowing a velocity of 1 ft. per sec. and a time of contact in the high current region of 1 sec. which has been found to be ample, plates 1 foot long and .8 foot wide would be suitable. To ensure fluidity of the tar it should not be colder than 60° at which temperature the sp. resistance is 23500. A voltage of 550 has been found most suited for this work and with such a voltage

over the plates of the machine described above the current would be 18.4 amperes. This would make the power necessary 10.1 K.W. or the total current consumption in the 4 hours as 40.4 K.W. hours.

This machine would require practically no attention and there would be no large depreciation charge. The only drawback is the high voltage required which is not usually obtainable in the neighborhood of such a plant.

12

This is that liquor which, in practice, is distilled over from the tar for the recovery of the alcohol, acetone, and acetic acid. The tar remaining in the still is known as " boiled tar " and is usually burned under the retorts.

Whether or not such a distillation is profitsble can only be determined by a knowledge of the prices of fuel, labor, and the efficiency of the distillation apparatus.

In aplant handling 225 cords per day the recovery of alcohol and acetone from this distillation would amount to 458 lbs. which is 4.15 % of the total yield. Calculating a complete recovery of the acetate the amount recovered would amount to 6.74 % of the total yield.

Mark 22.

This is a dark red oil with a smell resembling some of the benzens bodies. Assuming the abscence of any oxygen compounds and calculating all the oxygen to water the approximate composition of the hydrocarbons would be $C_8 H_8$. The composition of the liquid 22 would then be:-

Hydrocarbons (X)	55.8 %
Water	44.2

These hydrocarbons form addition products with sulphuric acid.

According to Veitch this liquid can be used as a substitute for gum turpentine and may be used in the manufacture of cheap varnishes and also as an illuminant.

Mark 32.

This oil has a peculiar persistent smoky odor distinct from that of phenol. It is slightly soluble in water, but miscible in all proportions with alcohol, ether, glacial acetic acid, chloroform, benzene, and carbon bi-sulphide. It dissolves in concentrated sulphuric acid to a red liquid which slowly changes

to a purple violet.

The oil is violently attacked by nitric acid and the solution so obtained, when concentrated, gives a yellow crystaline product, insoluble in ether, petroleum spirits, and alcohol. It is easily soluble in hot water from which it can be recrystalized without difficulty. This is without doubt the dye, Victoria yellow, which according to Thorpe is obtained by nitrating meta and para cresol.

Owing to the high iodine value of the oil the following tests were made to determine whether it could be used as a substitute for linseed oil in paints.

Drying Tests:-

To form a film the oil must necessarily oxidize in the air. By placind some of the oil on a weighed watch glass and exposing to the air and weighing at suitable intervals, oxidation can be detected by any gain in weight.

(a) Untreared 32 was spread on a watch glass and exposed to the air. Loss in weight for 10 days but no signs of film forming noted. For the weoght of thissample during the test see Plate VI.

(b) Some of 32 was boiled with 20 % manganese borate and 3 % litharge and subjected to the drying test. The sample lost weight but not as rapidlyas the untrated sample. It also showed a slight tendancy to thicken.

Some of the untreated oil was ground with chrome yellow

and the resulting paint spread on boards. The paint had a remarkable covering power but the time required for drying was 5 days. The chrome yellow showed a tendancy to darken in time. On cutting a painted board in two it was noticed that the oil penetrated to a depth of fully 5/16 inch in soft pine.

This oil, therefore, if mixed with some linseed oil give a paint of good quality as regards covering power and the preservation of the wood.

On heating a painted piece of iron to redness the paint showed no tendancy whatever to blister and only came off when the oil was completely carbonized.

The cost of this oil compared with that of linseed oil is low thus making it possible to prepare a paint at a much lower price.

An excess of the required amount of NaOH was added to some of the oil and the mixture boiled to complete saponification. The resulting soap was grained out with common salt. On attempting to close the soap with boiling water the soap was decomposed into the oil and alkali. Attempts were made with mixing the oil with tallow and using the mixture for soap stock. It was found after numerous trials that the maximum amount of oil which could be used and still obtain a stable soap was 1 part oil to 2 parts tallow. The soap thus obtained was of a brown color and

nearly insoluble in cold water. It dissolved readily in hot water and gave a good lather. It had a strong odor of creosote and should make a good antiseptic.

The disagreeable odor of this oil, which is practically impossible to remove or disguise, makes its use for most other purposes objectionable.

Mark 72.

The tests made as to the possibility of using this pitch as a waterproffing material showed that it was well adapted for such.

The results of the physical and chemical tests compare favorably with tests made on commercial road tars.

It could also be used as a substitute in the manufacture of black varnishes and japans and similar purposes.

We desire to acknowledge or indebtedness to Professor McCormack for numerous and valuable suggestions offered during this work.

We are further indebted to Mr. Shaw of Boyne City for the sample of crude tar used in this work and to Mr. E. W. McMullen for his kind assistance in securing data concerning the operation of large wood distillation plants.

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The Chemical Engineer (Mc Cormack)

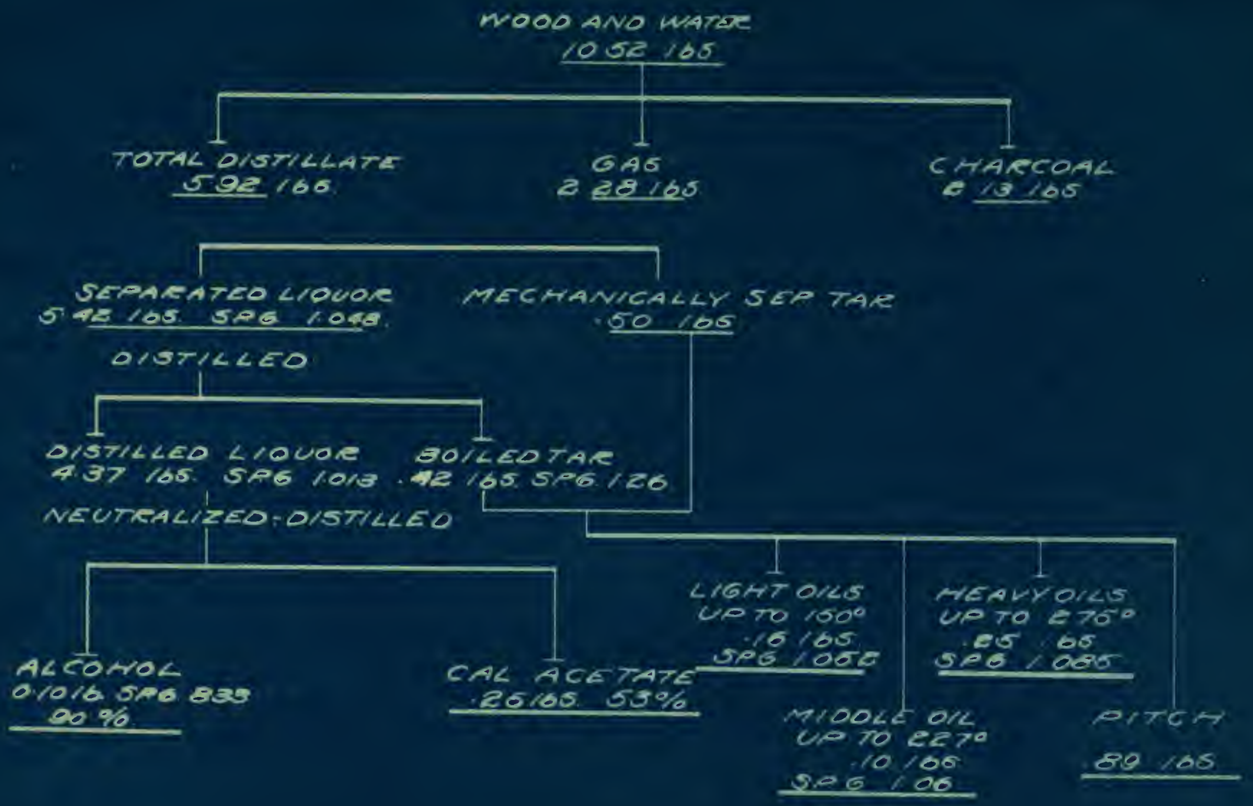

WOOD AND WATER
10.52 lbs
TOTAL DISTILLATE
5.92 lbs.
GAS
2.28 lbs.
CHARCOAL
2.13 lbs.
SEPARATED LIQUOR
5.42 lbs. SPG 1.048.
MECHANICALLY SEP TAR
.50 lbs
DISTILLED
DISTILLED LIQUOR
4.37 lbs. SPG 1.013
BOILED TAR
.42 lbs. SPG 1.26
NEUTRALIZED-DISTILLED
ALCOHOL
0.1016 SPG .833
90 %
CAL ACETATE
.26 lbs. 53%
LIGHT OILS
UP TO 150°
.16 lbs.
SPG 1.052
MIDDLE OIL
UP TO 227°
.10 lbs.
SPG 1.06
HEAVY OILS
UP TO 275°
.25 lbs
SPG 1.085
PITCH
.89 lbs

PLATE I.

PLATE II

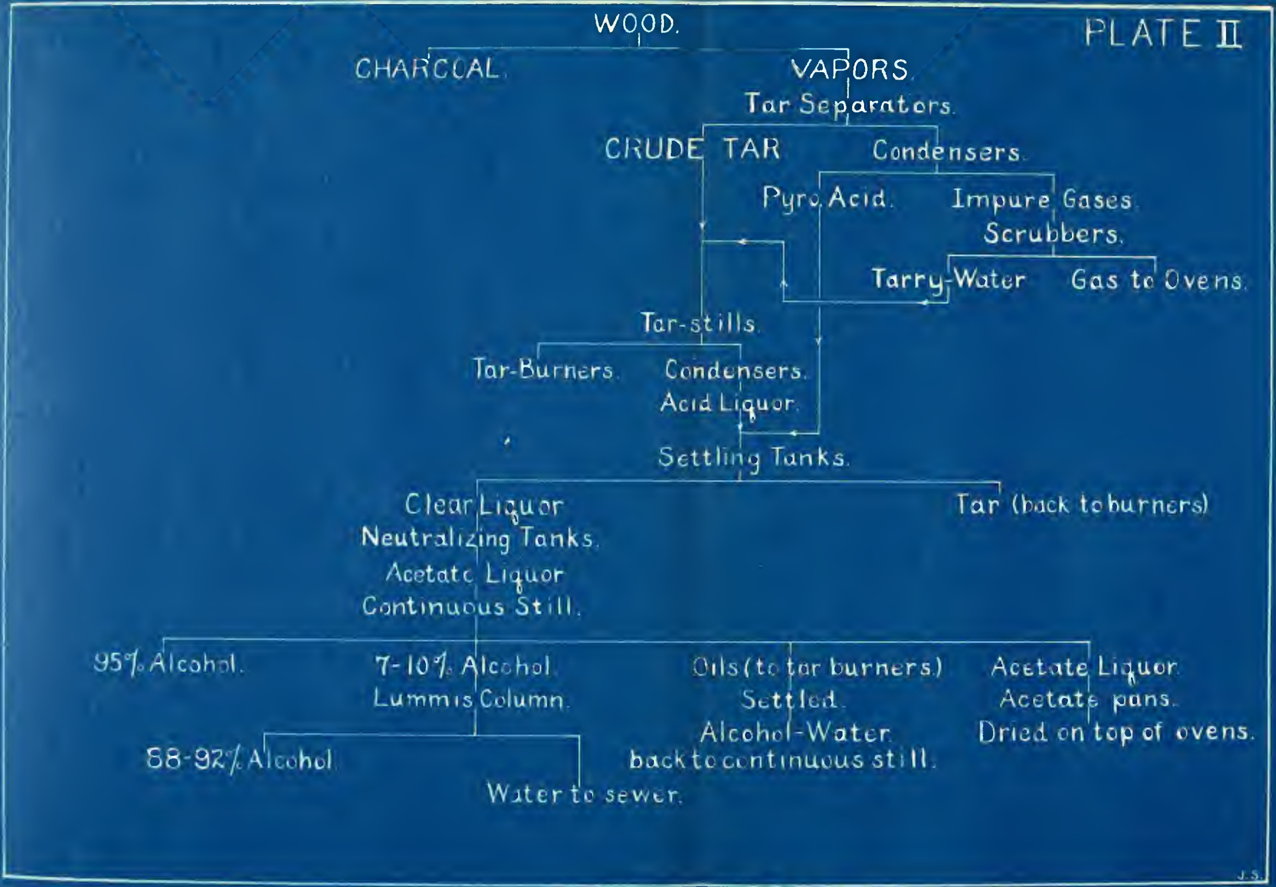

WOOD.
CHARCOAL.
VAPORS.
Tar Separators.
CRUDE TAR
Condensers.
Pyro. Acid.
Impure Gases.
Scrubbers.
Tarry-Water
Gas to Ovens.
Tar-stills.
Tar-Burners.
Condensers.
Acid Liquor.
Settling Tanks.
Clear Liquor
Neutralizing Tanks.
Acetate Liquor
Continuous Still.
Tar (back to burners)
95% Alcohol.
7-10% Alcohol.
Lummis Column.
88-92% Alcohol
Water to sewer.
Oils (to tar burners.)
Settled.
Alcohol-Water.
back to continuous still.
Acetate Liquor.
Acetate pans.
Dried on top of ovens.
J.S.

PLATE III

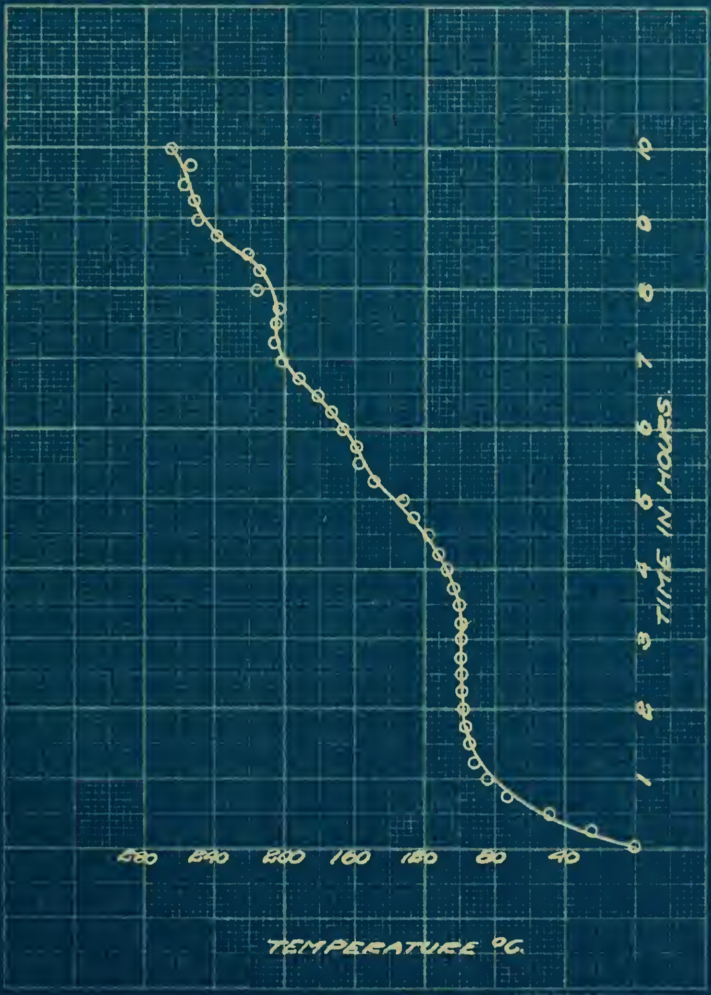
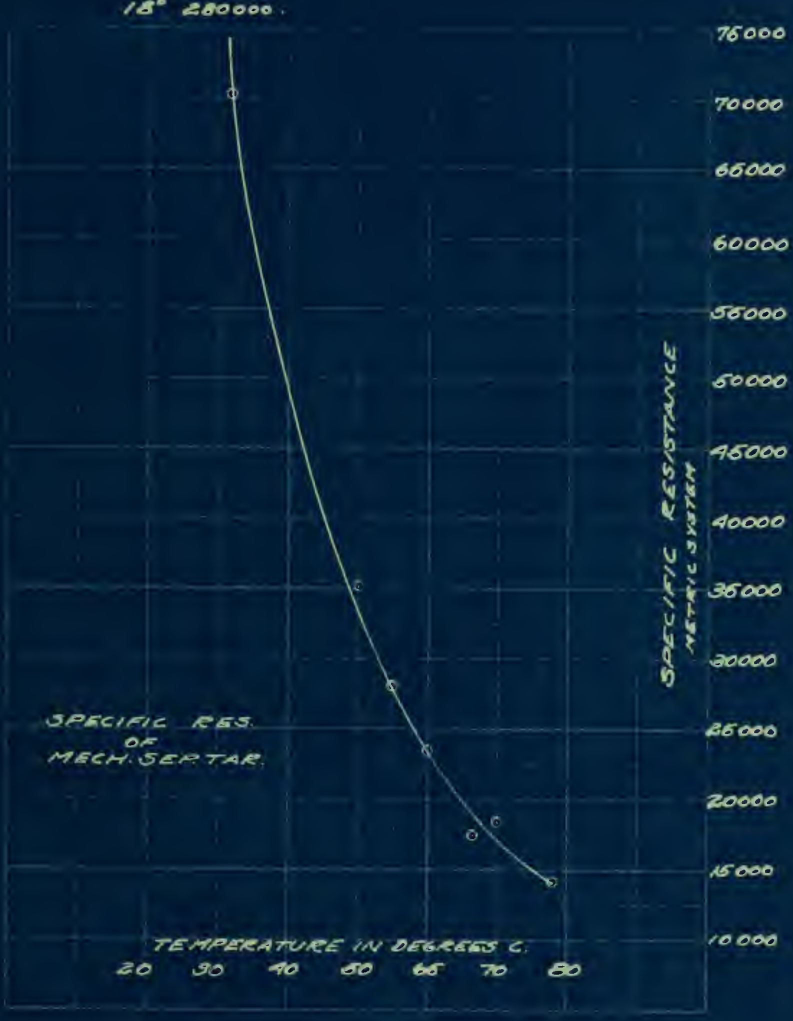
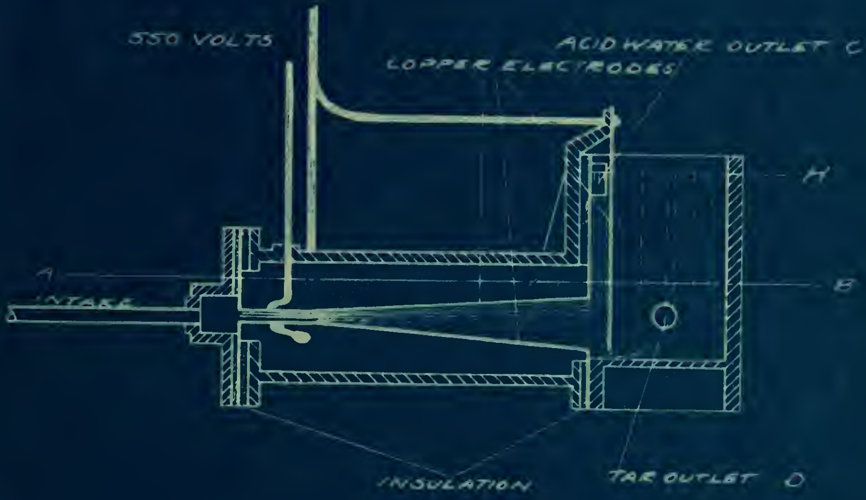
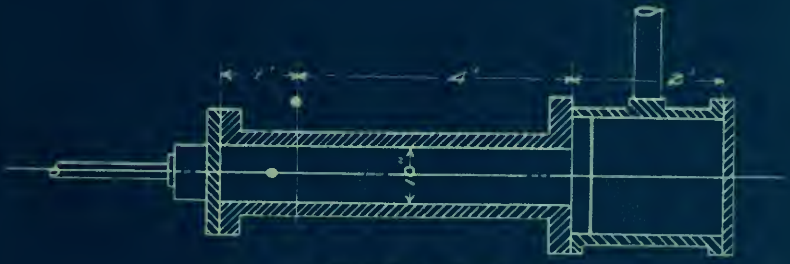

10
9
8
7
6
5
4
3
2
1
TIME IN HOURS.
280
240
200
160
120
80
40
TEMPERATURE °C.

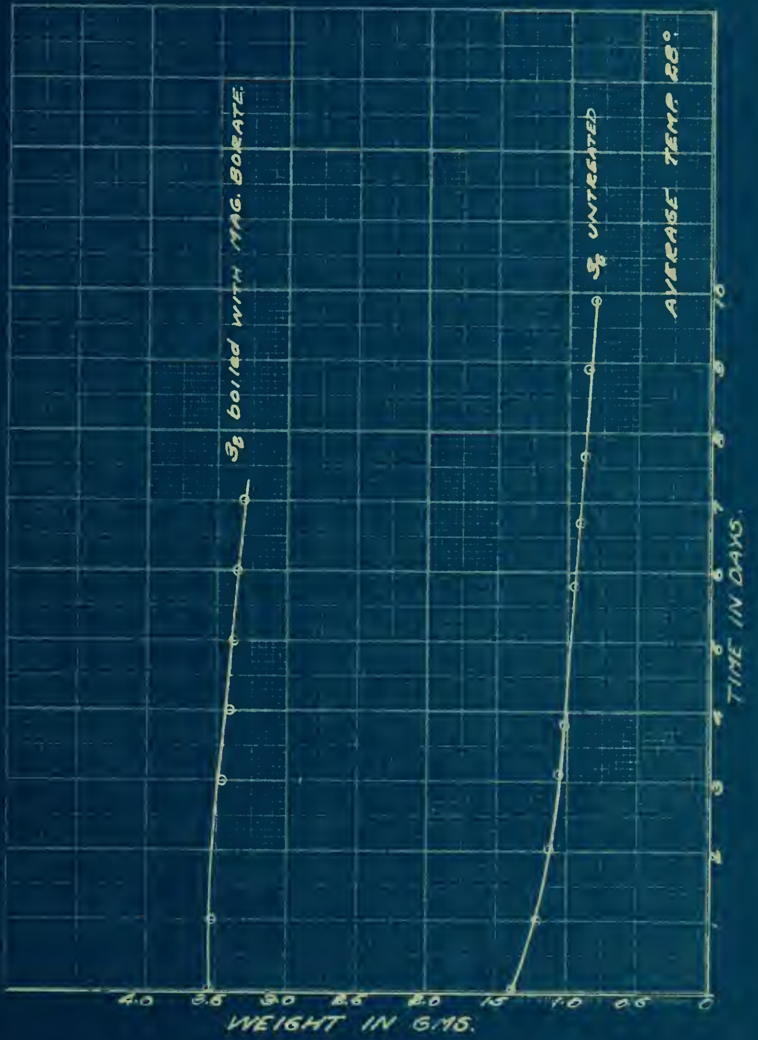
PLATE IV.


18° 280000.
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
SPECIFIC RESISTANCE
METRIC SYSTEM
SPECIFIC RES.
OF
MECH. SEP. TAR.
TEMPERATURE IN DEGREES C.
20
30
40
50
65
70
80


550 VOLTS
ACID WATER OUTLET C
COPPER ELECTRODES
H
A
INTAKE
B
INSULATION
TAR OUTLET D


10"

SECTION A-B


3b boiled WITH MAG. BORATE.
3a UNTREATED
AVERAGE TEMP. 68°
TIME IN DAYS
1
2
3
4
5
6
7
8
9
10
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
WEIGHT IN GMS.